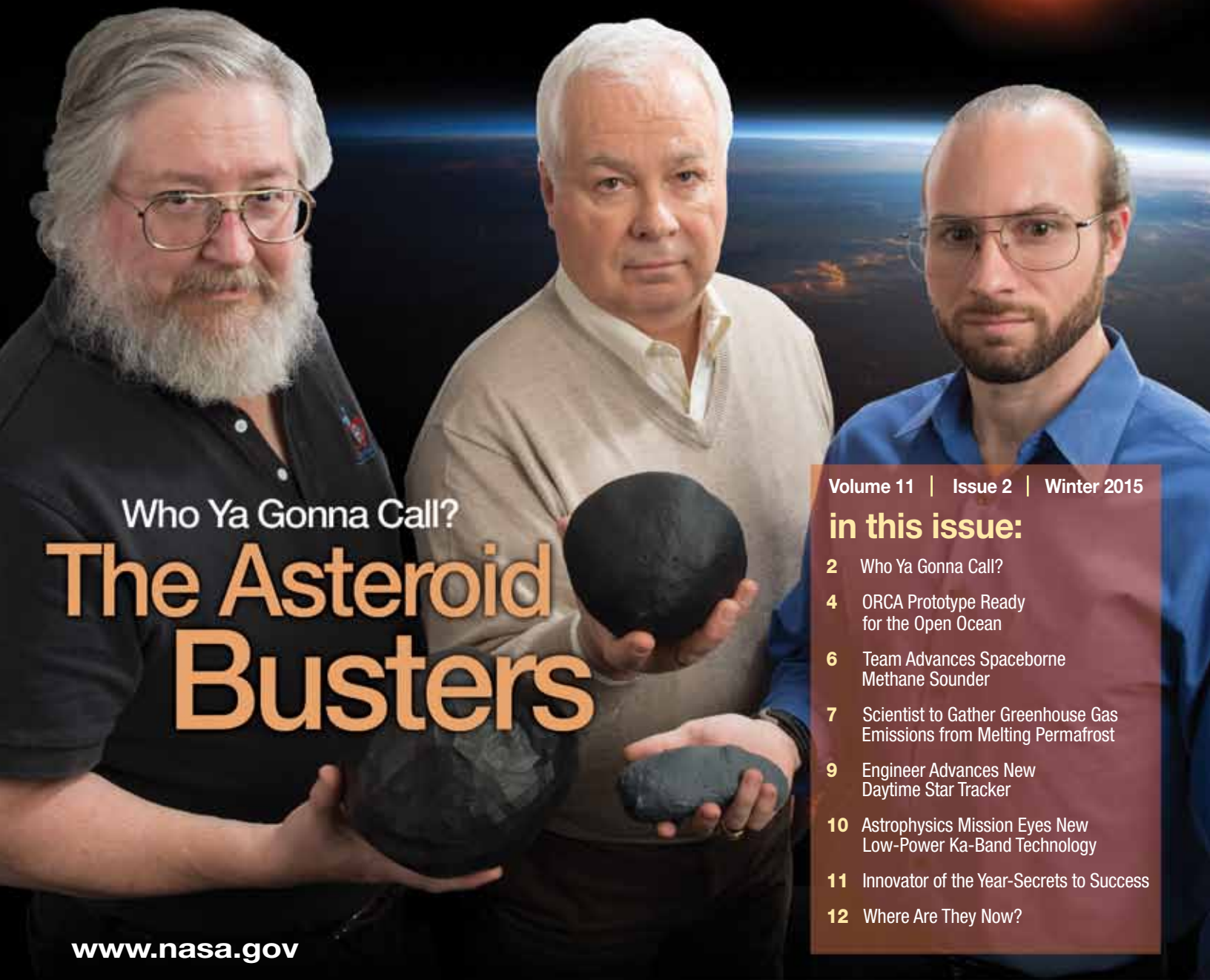
National Aeronautics and Space Administration

Cutting edge

Goddard's Emerging Technologies



Who Ya Gonna Call?
The Asteroid Busters

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in this issue:

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Who Ya Gonna Call? The Asteroid Busters!

NASA and the Department of Energy Partner to Evaluate Strategies to Deflect Potentially Hazardous Near-Earth Objects

Image Credit: Mark Boslough and Brian Carvey (DOE) and O. Kruglova

This artist's rendering shows the Chelyabinsk meteor as it streaked across the sky in 2013.

Two years ago, Mother Nature delivered a special belated valentine to people living 25 miles southeast of Chelyabinsk in Russia's Ural Mountains.

On February 15, 2013, she sent a 20-meter-diamter meteor that entered the atmosphere traveling at 12 miles per second — faster than Mach 60. It began to tear apart and within seconds exploded with the energy of a half mega-ton of TNT, which was roughly 20 to 30 times the energy released by the atomic bomb dropped on Hiroshima in 1945. The explosion created a shockwave that damaged thousands of buildings in six cities across the region and injured 1,500 people, whose injuries mostly were sustained from window glass that shattered when the shockwave arrived.

No one saw this ancient space rock coming.

Unique NASA-DOE Partnership Formed

However, the repercussions of that event — the most dramatic meteor airburst since the 1908 Tunguska impact blast in Siberia — are felt today, so much so, in fact, that NASA has been tasked to detect and characterize these inbound space objects. Goddard now is partnering with the National Nuclear Security Administration (NNSA), a semi-autonomous organization within the Department of Energy (DOE), to characterize these objects and research solutions for deflecting potentially hazardous near-Earth objects when given relatively little warning of their trajectory toward Earth. To

About the Cover

Goddard experts are working with the Department of Energy to evaluate strategies for deflecting potentially hazardous near-Earth objects. In the cover photo, Goddard's Joe Nuth, Bernie Seery, and Brent Barbee hold computer-designed subscale asteroid models.

In Addition...

The photo on the right shows additional team members (from left to right): Project Resources Analyst Lori Dellagatta, Project Manager Myra Bambacus, and Systems Analyst Ron Leung.

(Photo Credit (both images): Bill Hrybyk/NASA)

enable this important research partnership, NASA's Science Mission Directorate's Planetary Science Division recently signed an Inter-Agency Agreement with NNSA to codify the partnership.

"If the Chelyabinsk event had happened over heavily populated areas, we wouldn't be talking about mitigation strategies. We'd be preparing for them now," said Principal Investigator Bernie Seery, who helped forge the NNSA partnership and is now leading Goddard's multi-disciplinary team.

Photo Credit: Shutterstock

The largest part of the meteor that exploded over the skies near Chelyabinsk in Russia's Ural Mountains weighed 500 kg (1,102 lbs.) and fell into lake Chebarkul. It is shown here as part of an exhibition in Chelyabinsk on June 20, 2014.

Statistically, the most likely threats are those asteroids and comets measuring between 50-150 meters in diameter (164 to 492 feet). According to estimates, scientists have yet to discover perhaps up to a million of these near-Earth objects because their small sizes and other features make detection difficult. Making the situation more perilous is the fact that "these threats could involve relatively short warning times of a few years at most, possibly even less than a year," Seery said.

Goddard's Insights Tapped

With $1 million in funding over three years from NASA's Near Earth Object Planetary Defense Office, the Goddard team will thoroughly characterize three representative near-Earth objects. It wants to evaluate their observable or physical characteristics, Seery said. With that information, along with Goddard's insights into small-body physics, trajectory analyses, and mission planning, NNSA will tap its high-performance computer facilities at the Lawrence Livermore, Los Alamos, and Sandia National Laboratories to develop three-dimensional models of the various mitigation methods.

Although scientists have evaluated a number of mitigation strategies over the years, the simulations under this project will include "kinetic impactors" — spacecraft interceptors launched on hypervelocity-impact trajectories, much like NASA's Deep Impact mission in 2005. The spacecrafts' mass and velocity would deliver a certain amount of energy when they crashed into an asteroid at high speeds. The impact would impart a particular momentum and change the object's trajectory, causing it to deviate from its collision course with Earth.

The results of these complex simulations will better inform the planetary-defense and small-body scientific communities, while at the same time help NASA and NNSA engineers outline possible deflection or disruption missions, Seery explained. "This research effort is particularly challenging," Seery added, "because knowledge of how these objects were formed and the complexities of their motion is incomplete."

Comets, icy objects made up of water and ammonia, typically inhabit the icy cold regions of the outer solar system. "They can pose as much, if not more, of a threat," said Joe Nuth, a small-bdoy expert on the Goddard team. Exploding stars or other gravity-related perturbations can dislodge these objects and redirect their orbits into the inner regions of the solar system. Asteroids, on the other hand, are made up of materials with higher melting points, such as rock, iron, nickel, and silicon condensed in the inner solar system. They are particularly diverse, with chemical compositions that vary from carbonaceous to stony basaltic, and a few that are composed of nickel-iron.

Mitigation Research

Their diversity complicates determining how they

Continued on page 16

ORCA Prototype Ready for the Open Ocean

From left to right: Gerhard Meister, Bryan Monosmith, and Chuck McClain are shown here with the ORCA prototype, which is a strong contender for NASA's proposed Pre-Aerosol, Clouds, and ocean Ecosystem mission.

Its name refers to one of the biggest animals in the sea, but ORCA, the Ocean Radiometer for Carbon Assessment instrument, will be observing the smallest.

If selected for a flight mission — possibly on the Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) mission for which Goddard recently was awarded a Phase-A mission study — ORCA will study microscopic phytoplankton, tiny green plants that float in the upper layer of the ocean and make up the base of the marine food chain.

Conceived in 2001 as the next technological step forward in observing ocean color, the ORCA-development team used funding from Goddard's Internal Research and Development program and NASA's Instrument Incubator Program (IIP) to develop a prototype (*Goddard Tech Trends*, Summer 2008, Page 6). Completed in 2014, ORCA now is a contender as the primary instrument on PACE.

Should it be chosen, ORCA will take ocean-color monitoring to the next level, helping scientists to more precisely measure marine photosynthesis, which is key to the carbon cycle and the ocean food chain.

Like its predecessors that also measured ocean color, the instrument will observe phytoplankton, which blooms en masse, covering hundreds of square miles of the sea surface at once and leaving a trail that is clearly visible from space. In particular, researchers will observe global changes in ocean color to estimate concentrations of chlorophyll, the pigment plants use for photosynthesis — the process during which the tiny plants convert energy from the sun and carbon dioxide into organic compounds that support life.

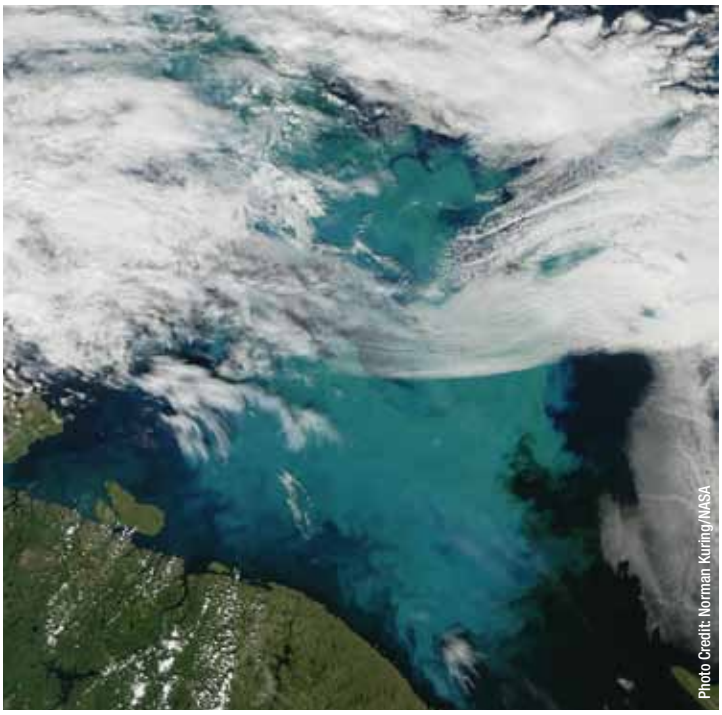
About a fourth of man-made carbon dioxide ends up in the ocean, said Chuck McClain, former ORCA principal investigator with Goddard's Ocean Color Group. "The ocean is a big sink for CO2 and part of that sink involves ocean biology."

ORCA builds on the work Goddard scientists and engineers pioneered in the development of ocean color sensors. Goddard's proof-of-concept — the Coastal Zone Color Scanner that flew on Nimbus-7 from 1978 to 1986 — was the first sensor to demonstrate that ocean chlorophyll could be measured from space. NASA's Sea-Viewing Wide Field-of-View Sensor mission, which col-

lected data from 1997 to 2010, was the first flagship mission to routinely observe ocean color for long-term climate research. Currently, researchers employ the Moderate Resolution Imaging Spectroradiometer on NASA's Terra and Aqua spacecraft and the Visible Infrared Imager Radiometer Suite aboard the Suomi National Polar-orbiting Partnership satellite.

ORCA's Distinguishing Characteristics

What sets ORCA apart from its predecessors is its hyperspectral capability. Instead of observing a handful of discrete bands at specific wavelengths reflected off the ocean, ORCA measures a range of bands, from 350 nanometers to 900 nanometers at five-nanometer resolution. Instead of having to choose one shade to represent each color of the rainbow, ORCA sees the entire rainbow, including the color gradations of green that fade into blue. In addition to the hyperspectral bands, the instrument has three short-wave infrared bands that measure specific wavelengths between 1200 and 2200 nanometers for atmospheric applications.



The area in this Aqua-MODIS image is located immediately north of the Scandinavian Peninsula. The intersecting waters, plus stiff winds, promote mixing of waters and nutrients from the deep. The phytoplankton blooms are seen as bluish-green in color.

"That's over a hundred wavelengths we measure," McClain said. "We start way down in the ultraviolet, really short wavelengths, and we go clear out to the short-wave infrared." To date, no satellite ocean-color instrument offers this wavelength range. More and continuous wavelengths mean more data and more refined observations of the upper layers of the ocean, he said.

"When you have more information about the spectrum of the water, then you can do a better analysis of what is in the water. Most phytoplankton species are green, but they have different types of green, so they have slightly different spectra. You need a lot of different wavelengths to discern these differences," said Gerhard Meister, ORCA's principal investigator.

In particular, researchers will obtain more accurate measurements of chlorophyll concentrations. The concentration reflects the size of the phytoplankton bloom and how much carbon it holds. Detecting chlorophyll in various wavelengths also will allow researchers to distinguish between types of phytoplankton. Researchers also could collect information on the other types of particles present, such as suspended sediments in coastal regions.

The ORCA prototype has a scanning telescope designed to sweep across 2,000 kilometers (1,243 miles) of ocean at a time. It collects light reflected from the sea surface that then passes through a series of mirrors, optical filters, gratings, and lenses. These components direct the light onto an array of detectors that cover the full range of wavelengths.

The goal of the prototype's development was to get ORCA as close as possible to flight readiness with minimal risk, McClain said. "Part of the IIP project was not only to build it, but also go through a very thorough performance evaluation," he said. "We tried to certify that we met all the PACE performance requirements, everything that we could do without having a flight instrument. We were successful in doing that."

Meister concurs. "When we got actual data from the instrument, we realized, wow, this is a good instrument," he said.

Now that the prototype is complete and the PACE mission has been awarded a Phase-A mission study, the ORCA team is waiting for the green light to begin working on a version that will fly in space. ❖

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EDITOR'S NOTE

Methane emissions are an increasing concern for scientists studying climate change. Goddard scientists are pursuing two different measurement techniques that complement one another. Here, CuttingEdge examines both approaches and shows how they benefit the scientific community.

Measuring Another Greenhouse Gas

Scientist Advances Methane Sounder

A Goddard scientist who has played a key role developing and demonstrating a new technique for gathering around-the-clock global carbon-dioxide (CO_2) measurements is applying the same general principles to develop a new laser instrument sensitive to another greenhouse gas — methane.

Photo Credit: Emily Schaller

A Goddard team, led by Principal Investigator Haris Riris (second from left), demonstrated the prototype Methane Sounder aboard NASA's DC-8 aircraft in 2011. From left to right: Kenji Numata, Haris Riris, Martha Dawsey, Anand Ramanathan, Stewart Wu, and Steve Li.

With $1.2 million in recently awarded NASA funding, Goddard scientist Haris Riris and his team will continue advancing the Methane Sounder that operates much like its close cousin, the CO_2 Sounder Lidar developed by Riris's close collaborator, Goddard scientist Jim Abshire. The next-generation instrument will be able to provide remotely collected, high-resolution, highly accurate, around-the-clock global methane measurements should it ultimately fly as a spaceborne instrument.

Haris and his team, including Kenji Numata and Stewart Wu, will use the new funding to further improve the prototype instrument and then test it during a NASA DC-8 aircraft campaign later this year. The goal is to advance the concept to a point where it perhaps could be flown on a proposed mission, such as NASA's Active Sensing of CO_2 Emissions over Nights, Days, and Seasons (ASCENDS).

Community Would Benefit

"We're working to come up with a design that we think will work in space," Riris said. Since initially flying the concept on a DC-8 research aircraft in 2011, he said his team has developed a better instrument. "Our goal is to prove that the technique works and meets precision and accuracy requirements."

The scientific community would benefit enormously from such a capability, Riris said. "Understanding current global methane trends is a difficult challenge that cannot be resolved by existing measurement networks or current satellite observations," he said. "Our technology directly addresses the objectives of NASA's Earth Science Decadal Survey for measuring methane and water vapor in the atmosphere."

On Earth, methane is an important greenhouse gas produced by certain types of bacteria in soils and in the digestive tracts of some animals. Large quantities of methane also are produced as a result of forest fires and human industrial processes.

Although carbon dioxide, another greenhouse gas, lingers in the atmosphere longer, methane is in some respects more worrisome. It is more potent and effective at absorbing heat. Exacerbating concerns is the fact that large quantities of the gas reside beneath permanently frozen ground in the Arctic. As the permafrost melts, which scientists say currently is occurring, more of this gas is

Continued on page 8

Scientist to Gather Greenhouse Gas Emissions from Melting Permafrost

A Goddard scientist who has developed a novel suitcase-size instrument to measure column carbon dioxide and methane is taking her recently patented instrument on the road this summer to comprehensively measure in a first-of-its-kind investigation emissions of these important greenhouse gases from Alaska's melting permafrost.

Emily Wilson, who received a patent in April 2014 for her miniaturized Laser Heterodyne Radiometer (mini-LHR), has won nearly $1 million in NASA research funding to carry out the multi-disciplinary field campaign at three sites — each representing a different type of permafrost — near Fairbanks in June. Her team has designed a unique and comprehensive experiment that records permafrost depth and structure, meteorological data, and concentrations of methane and carbon dioxide during the seasonal ground melt.

Photo Credit: Bill Hrybyk/NASA

Scientist Emily Wilson poses with the exterior shell of a potential CubeSat. It would carry a version of her miniaturized Laser Heterodyne Radiometer — an instrument for which she received a patent in 2014.

Multi-Disciplinary Approach

"This is the first time that anyone has combined these types of measurements to provide a holistic, or big-picture, view of the evolution of and the atmospheric response to permafrost melt," Wilson said. "With the global mean temperature rising, the release of these gases could create an amplified effect. These data will allow us to estimate fluctuation of emissions from the melting permafrost."

Permafrost is permanently frozen soil. Comprising 24 percent of the Northern Hemisphere, permafrost contains old organic carbon deposits — some relics from the last glaciation — that are locked beneath the surface. Scientists have observed that more of the permafrost's upper layer, or the active layer, is melting each summer, creating concern that the thawing could lead to significant greenhouse-gas emissions.

Further exacerbating the situation is the fact that while methane doesn't linger as long as carbon dioxide in the atmosphere, it is more potent and effective at absorbing heat. It creates a momentum, where increased emissions lead to more warming, which, in turn, accelerates the thaw.

Highly portable, the mini-LDR is ideal for permafrost studies, Wilson said. Made up of commercially available components, the instrument literally can go anywhere to measure carbon dioxide and methane in the atmospheric column — that is, the levels of these gases in a vertical column extending from

Continued on page 8

Methane Sounder, *continued from page 6*

released into the atmosphere, creating a feedback mechanism where emissions lead to more warming. This, in turn, accelerates the melting.

Although some satellite instruments can detect and map Earth's methane, Riris's concept gives scientists something they don't currently enjoy — 24-hour coverage. In sharp contrast to many methane instruments, including those used in ground-based investigations (see related story, page 7), the Methane Sounder employs its own light source — a tunable laser transmitter. Although laser light cannot penetrate thick clouds, it can measure through thin clouds and particles and at night, which is impossible for passive systems that rely on reflected sunlight for their source of illumination.

To gather methane data, the team's instrument works much like the CO2 Sounder. It bounces a laser light tuned to a specific wavelength band — in this case, 1.65 microns — off Earth's surface. Like all atmospheric gases, methane will absorb the light as it travels back to the orbiting instrument. The more methane molecules along the path, the deeper the absorption lines as measured by the instrument's detectors.

Challenging Technology

Although Abshire has proven that sounders are effective at detecting carbon dioxide (*CuttingEdge,* Fall 2011, Page 4), adapting the concept to methane is more challenging, Riris conceded.

"We have been measuring carbon dioxide longer and the wavelength range for carbon dioxide — 1.57 microns — is easier to work in. It's very difficult getting a laser at 1.65 microns," he said. As a result, the team is attempting to overcome the obstacle by combining two wavelengths and using a crystal to create the desired wavelength band that methane absorbs.

Given the increased concern over methane emissions — particularly in the Arctic where it's difficult gathering data using passive instruments — the addition of a methane-measuring instrument on a mission like ASCENDS is not outside the realm of possibilities, Riris said. "We're not the only ones working on the problem, but we think we have the better solution. If we can demonstrate that we can measure methane, the community will respond." ❖

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Permafrost, *continued from page 7*

the ground to space. Currently, the only ground-based network that measures these two greenhouse gases in the atmospheric column is the Total Carbon Column Observing Network. However, only two of its 22 sites are in the U.S. — none in the Arctic regions.

"We're targeting areas where there is limited coverage," she said.

To prepare for the campaign, Wilson used Goddard Internal Research and Development (IRAD) program funding to further ruggedize her instrument and make it more sensitive. She added a satellite communications port to remotely retrieve data, a thermally controlled instrument housing to protect the instrument from changing temperatures, and a solar grid and battery storage system for powering the instrument in remote locations.

Other Efforts Afoot

Wilson, meanwhile, isn't resting on her successes. A small company in California's Silicon Valley has expressed interest in potentially commercializing her patented design, she said. She's also using IRAD funding to transition the mini-LHR into a six-unit (6U) CubeSat. These compact spacecraft typically are less expensive to build and launch. She has submitted a patent application for this design, as well.

Should the CubeSat-compatible device become a reality, she said the capability would allow NASA to target regions currently underrepresented in satellite observations — particularly in the high-latitude Arctic areas increasingly becoming more important in climate studies due to the melting permafrost.

The CubeSat, which Wilson has named COWSat (Carbon Observing Worldwide Satellite), would measure vertical distributions of carbon dioxide, methane, and water vapor. It also could fill data gaps and provide cross-validation of larger satellite missions, such as the Greenhouse gases Observing Satellite and NASA's Orbiting Carbon Observatory. "With this spacecraft, we could target specific geographic regions of interest, gathering emissions data in the tropics or developing countries," Wilson said. ❖

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Engineer Advances New Daytime Star Tracker

Scientists who use high-altitude scientific balloons are in a sense getting gypped. Although the floating behemoths that carry instruments far into the stratosphere can stay aloft for hours on end, data collection typically happens only during the night and those instruments that do operate during the day are limited in their fields of view.

An engineer at NASA's Wallops Flight Facility (WFF) is working on a low-cost, off-the-shelf solution to overcome the challenges.

Under WFF's Balloon Program, Scott Heatwole and his team are developing a precision attitude sensor or star tracker that would locate points of reference, or stars, during daylight hours. These points of reference serve as landmarks that help orient the instrument so that it can find a target.

Heatwole is developing it for the Wallops Arc Second Pointer (WASP), which then would use the star tracker's data to point a balloon-borne scientific payload with sub arc-second accuracy and stability (*CuttingEdge*, Winter 2014, Page 8). Currently, WASP employs the commonly used ST5000 star tracker. However, this device cannot image in the daytime even at 120,000 feet where scientific balloons operate. Though relatively dark at those altitudes, the scattering of sunlight off the atmosphere can overwhelm the starlight in most star cameras.

"A precision attitude sensor capable of working in the daylight would extend science operations through the day which would significantly increase the amount of science collected," Heatwole said. "Currently, the only precision attitude sensor available in daytime is a sun sensor, and this isn't ideal because it provides only two axes of attitude and is not precise over a range of targets across the sky."

Although others have built custom star trackers that enable 24-hour science gathering, no one has designed a low-cost package that includes hardware and algorithms necessary to eliminate excess visible light in real time. "That's what we're trying to do," Heatwole said, adding that his device consists of a commercial firewire camera attached to a lens and baffle that help eliminate visible light, allowing it to sense points of reference in the near-infrared.

In 2014, a prototype flew on two WASP missions. The first, a reflight of the HysperSpectral Imager for Climate Science, collected radiance data as WASP pointed the instrument toward the Earth, the sun, and the Moon. "We wanted to see what the star tracker saw at 120,000 feet," Heatwole said, adding that the mission also carried a sun sensor that did the heavy lifting during the balloon flight. The second, launched in October, carried the Observatory for Planetary Investigations from the Stratosphere. Its mission was to gather time measurements of Jupiter's atmospheric structure — a challenge because the planet is a bright object. "Our algorithm didn't work as we had hoped," he said. It failed to filter the excess light as expected.

Wallops engineer Scott Heatwole and his team are developing a precision attitude sensor that would locate points of reference, or stars, during daylight hours.

He is unfazed, though. He plans to fine-tune the algorithms to eliminate the excess light and then retest the technology during a sounding rocket flight this summer and WASP missions in 2016 and 2017. "No company is going to develop an off-the-shelf daytime star tracker and put all the components in one package," he said. "WASP requires a star tracker that is capable in the daytime. That's what we hope to create." ❖

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Breaking Through the Noise

Proposed Astrophysics Mission Eyes Use of New Compact, Low-Power Ka-Band Technology

The radio frequency that many NASA missions use to communicate with spacecraft — S-band — is getting a bit crowded and noisy, and likely to get more jammed as science missions demand higher and higher data rates.

Goddard technologists just may have a solution, particularly for potential missions that plan to operate in low-Earth orbit and have limited real estate to accommodate communications gear.

Goddard technologists Mae Huang and Victor Marrero-Fontanez have collaborated to test and verify components of a prototype end-to-end Ka-band space communications system. In this photo, Huang is holding a test board upon which her Ka-band/microwave design is mounted and bonded.

Under two different research and development projects, technologists Mae Huang and Victor Marrero-Fontanez have collaborated to test and verify components of a prototype end-to-end Ka-band space communications system, which promises significantly higher data rates — a whopping 2.4 gigabits of data per second (Gbps) — over more traditional S-band systems, which theoretically could achieve data rates of 90 megabits (Mbps).

Huang is working with Jeffrey Jaso — a pioneer in Ka-Band communications — to develop a Ka-band transmitter. Marrero-Fontanez, meanwhile, is designing Ka-band antennas to receive the Ka-band signals. Huang and Marrero-Fontanez plan to assemble a prototype in early 2015.

Huang also will be delivering an engineering test unit of her transmitter to a Goddard team that is considering the technology's use on the proposed Wide-Field Infrared Survey Telescope (WFIRST). WFIRST, a next-generation observatory designed to carry out wide-field imaging and slitless spectroscopic surveys of the near-infrared sky, will look in particular for dark energy and exoplanets. Due to its heavy data-rate requirements, the project provided Huang with some funding to advance her technology, she said.

WFIRST isn't the only mission looking for a compact, low-power, end-to-end system. Future Earth-observing missions also are expected to generate higher and higher data rates that could overwhelm the S-band allocations shared by commercial operations and missions using NASA's Near-Earth Network and Deep Space Network.

"In a sense it's like rush-hour traffic. When you start your morning commute, you may notice fewer cars, but before you know it, you're in stop-and-go traffic as more cars merge onto the highway. The world's frequency bands are beginning to look a lot like bumper-to-bumper traffic," she said. "Cell phones, streaming video, and data communications are all placing big strains on available bandwidth. Meanwhile, commercial businesses are putting pressure on the government to free up other bands, pushing more federal operation into the S-band that NASA uses. Couple that with NASA's expected need to transmit and receive greater and greater amounts of mission data, something will have to give."

Although NASA has had the Ka-band allocation for years and has used the frequency on past missions, the band has remained underused for a variety of reasons, mainly because of limited technology development, perceived technical challenges, among other things, Marrero-Fontanez said. "However, NASA has always had a strong interest in using this frequency allocation," he added, "particularly because it can significantly increase

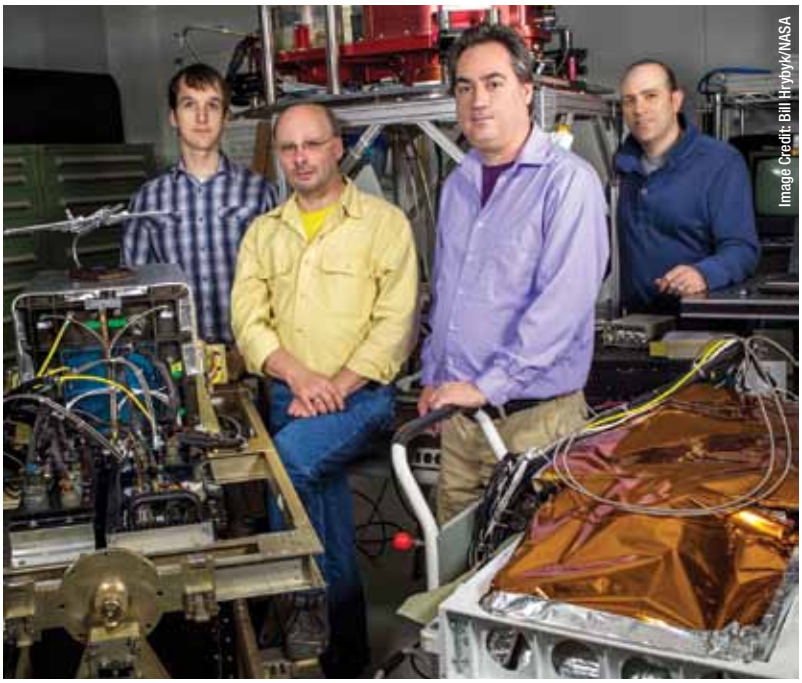
Continued on page 15

IRAD Innovator of the Year Offers Secret to Success: He Leverages

Goddard scientist Matt McGill, who has earned a reputation over the years for consistently delivering technologically advanced Earth-observing instruments on budget and on time, has a secret: the 2014 "IRAD Innovator of the Year" knows how to work the system.

He leverages.

McGill and his team, including Andrew Kupchok, Stan Scott, and John Yorks, received Goddard's Office of the Chief Technologist's annual award in early December due to their success designing and building three different instruments vital to climate-change studies and pursuing new platforms upon which to fly the innovative concepts — a notable achievement given that all three were designed, built, and delivered in just a few years' time.



Goddard's FY14 IRAD Innovators of the Year include from left to right: Andrew Kupchok, Matt McGill, Stan Scott, and John Yorks. They are posing with some of the instruments they developed over the years: (left) Cloud Physics Lidar, (center top) Airborne Cloud-Aerosol Transport System, and (right) Global Hawk Cloud Physics Lidar.

"In all cases, the group built these important climate-change instruments with a small team, a streamlined process, and a build-to-cost mentality," said Goddard Chief Technologist Peter Hughes, who bestows the award annually on those who achieve significant results that benefit NASA and others in the communities they serve. "He and his team also leveraged multiple NASA technology resources, including the SBIR (Small Business Innovation Research) and ESTO (Earth Science Technology Office) programs. The team's success is a testament to its can-do spirit and vision, personifying the attributes that make our innovators among the agency's most effective."

Latest Venture

Although McGill asserted that others deserved the recognition more, he did agree that leverage contributed significantly to the on-time, on-budget delivery of the three instruments. His approach to instrument development also will figure significantly in his latest venture — building the Cloud Aerosol Multi-Angle Lidar (CAMAL). This autonomous instrument will profile the atmosphere at multiple off-nadir angles — that is, not in a column directly below the instrument's field of view — a tough measurement technique, McGill said.

To obtain this measurement, McGill is incorporating into CAMAL a scanning transceiver developed by an SBIR awardee, Litespar, Inc., based in Tucson, Arizona.

"We work with SBIR-funded companies and make certain that the technologies they are developing will perform as described," McGill said, referring to the government program that awards technology seed funding to companies with fewer than 500 employees. "We work in lockstep with them and make sure what is delivered will be able to be integrated into our instrument concepts. In other words, we use their deliverables, which saves time and money," McGill added. While Litespar is providing the all-important scanning transceiver, McGill and his team "will take care of everything else, including detector development and integration."

McGill said he employed the same approach — incorporating technologies developed under SBIR, the ESTO program, and Goddard's Internal Research and Development (IRAD) program — to

develop the other three instruments for which McGill and his team received the innovator award.

Approach Used to Develop Other Instruments

For example, the Cloud-Aerosol-Transport System (CATS), which NASA deployed on the International Space Station in early January 2015, is demonstrating for the first time three-wavelength active optical (lidar) remote sensing. In addition, it is showcasing how lower-cost spaceborne experiments can take advantage of existing platforms — the International Space Station — thus paving the way for less costly experiments on smaller missions, with potentially more rapid access to space.

Another instrument, the proof-of-concept Multiple Altimeter Beam Experimental Lidar (MABEL) — built in just one year, from concept, design, procurement, assembly, and first flight — proved that photon counting worked at high altitude and was suitable for the Ice Cloud and land Elevation Satellite-2 (ICESat-2) mission.

"Usually it takes three years under an ESTO Instrument Incubator Program award to develop a proof-of-concept instrument," McGill said. "But we condensed this down to a year. People broke their backs getting this done."

And long before others began considering unmanned aerial vehicles (UAVs) as potential platforms for research, McGill saw an opportunity for his already successful Cloud Physics Lidar. Until then, the instrument had flown exclusively on piloted research aircraft. With Goddard's IRAD funding, he retrofitted the "airplane" instrument so that it would be compatible with an autonomous platform. Two years later, the UAV-compatible instrument debuted on the maiden flight of NASA's Global Hawk aircraft. Now, it's an important player in NASA's Hurricane and Severe Storm Sentinel mission.

"We work with these R&D programs and see it as a useful investment. They short-circuit the technology-development and procurement cycles. This is how we're getting it done," McGill said. ❖

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EDITOR'S NOTE

In celebration of its 10th anniversary, CuttingEdge (formerly known as Tech Trends) will be publishing articles that highlight past achievements. Here we feature Goddard's past IRAD Innovators of the Year.

Where Are They Now?

Past Innovators Share Successes

Eight years ago, the Office of the Chief Technologist rolled out the "IRAD Innovator of the Year" award as a way to recognize those who demonstrated exceptional technological achievement. Here's a look at what past recipients are doing these days.

Danny Glavin

Back in 2007, astrobiologist Danny Glavin was on a roll, winning a highly coveted NASA award to define and test a suitcase-size instrument that could analyze gases on the Moon and other solar system bodies. Although his original instrument concept may never fly, a miniaturized high-temperature oven that Gavin advanced for the Volatile Analysis by Pyrolysis of Regolith (VAPoR) is being used on a potential next-generation mass spectrometer now being developed by one of Glavin's colleagues, Will Brinckerhoff (*CuttingEdge*, Summer 2013, Page 10). Talk about the power of leverage, Glavin says.

Now the associate director for strategic science with Goddard's Solar System Exploration Division, Glavin remains an active player in the

astrobiology and planetary science communities. Since 2007, Glavin has won the Meteoritical Society's highly acclaimed Nier Prize for young scientists and he and other team members helped secure the next New Frontiers mission — OSIRIs-REx (Origins Spectral Interpretation Resource Identification Security-Regolith) — that will return a large, pristine sample of an asteroid for detailed analysis.

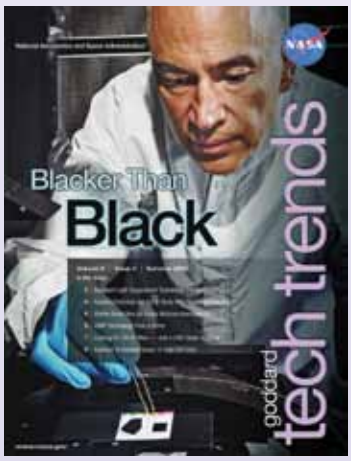
His analysis of data gathered by Curiosity's Sample Analysis at Mars (SAM) instrument also has earned him headlines. At the American Geophysical Union meeting in December 2014, the SAM team announced that some of the carbon-containing compounds SAM detected, such as chlorinated alkanes and benzene, came from organic matter in ancient martian rock, not from earthly contaminants — a milestone in their search for signs of ancient life on Mars.

Jennifer Eigenbrode

Jennifer Eigenbrode, another Goddard astrobiologist with expertise in detecting and deciphering organic molecules found in rocks, sediments, and ice, earned the center's top technology award in 2009 for developing an experiment that secured a last-minute slot on the Goddard-developed SAM instrument, one of several aboard the Curiosity rover.

Her IRAD-funded research proved that thermochemolysis — the combination of heat and a specific chemical called tetramethylammonium hydroxide in methanol (TMAH) — would significantly enhance SAM's ability to analyze large carbon molecules, potential precursors or artifacts of life that are made up of smaller molecules. "SAM is now on Mars, but we haven't used the experiment yet," Eigenbrode said. "If we come across something that looks especially promising, we'll use the experiment. We are waiting for the right opportunity."

In the meantime, Eigenbrode says she's staying busy analyzing SAM data and studying the effects of ionizing radiation on organic matter and the preservation of signatures of microbial life in rocks regarded as analogs of Mars. She has participated in numerous field expeditions to the Atacama Desert in Chile, Australian Outback, mountains and glaciers in the high Arctic, and remote salt lakes.

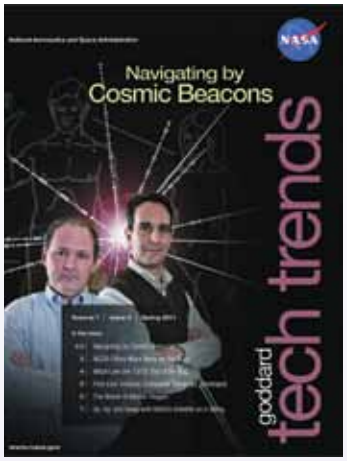


John Hagopian

Since demonstrating that a "blacker-than-black" nano-coating was at least 10 times more effective than black paint at suppressing stray light, technologist John Hagopian has hurdled a number of other challenges in his quest to fly this technology on a future NASA mission.

The 2010 IRAD Innovator of the Year, who has spent the past six years advancing the nanotechnology, has filed a patent application, flown samples on the International Space Station for testing, coated complex, 3D components designed for a variety of scientific applications, and proved that the technology is beneficial to several other uses, in addition to stray-light suppression.

The technology, a thin, highly uniform coating of multi-walled nanotubes made of pure carbon about 10,000 times thinner than a strand of human hair, absorbs 99.5 percent of the light in the ultraviolet and visible and 99.8 percent in the longer infrared bands due to the fact that the carbon atoms occupying the tiny nested tubes absorb the light and prevent it from reflecting off surfaces. Hagopian says the coating is ripe for infusion. "We're at the point where we're well on the way to flying the coating on a NASA mission," he said.



Keith Gendreau and Zaven Arzoumanian

When Goddard scientists Keith Gendreau and Zaven Arzoumanian were named top innovators in 2011, they had just received $250,000 to develop a Phase-A study for the proposed Neutron Star Interior Composition Explorer/Station Explorer for X-ray Timing and Navigation Technology (NICER/SEXTANT) mission. NICER/SEXTANT now is a full-blown mission.

Expected to deploy on the International Space Station in 2016, NICER/SEXTANT will gather scientific data revealing the physics of dense matter in neutron stars and, from the same platform, demonstrate the potentially revolutionary use of pulsars as a means to navigate to the far reaches of the solar system and beyond. The payload also may help demonstrate X-ray communication, which has the potential to provide high-data rates over vast distances.

"We're on a good track," Gendreau said, adding his team passed the critical design review in 2014 and has finished nearly half of the instrument's optics. In the fall, the team put together the optical bench and planned to complete and install the optics in January 2015. By next year, the instrument should be fully integrated, Gendreau said. In addition, one of the effort's key components, an X-ray source that the team is using to test the instrument, will be patented because of its potential applications across a variety of fields, Gendreau said.

Stephanie Getty

In 2012, Stephanie Getty earned recognition because of her can-do spirit and remarkable ability to devise, build, and test innovative instrument components for detecting organic compounds, including life-sustaining amino acids, on comets, asteroids, and the icy moons in the outer solar system.

That year, her wide-ranging efforts paid off. She received several million dollars in NASA research funding to advance two new instrument concepts, which borrowed heavily from instrument components she and her colleagues had developed under previous Goddard and NASA R&D-funded efforts.

Over the ensuing years, she has been busy. "A good chunk of my time is still devoted to advancing those instrument concepts," she said. "Both are great for missions to icy or small carbonaceous bodies, especially for mitigating concerns of terrestrial contamination." Since she was recognized, she also has contributed to a number of recent planetary mission and instrument proposals, was promoted as Assistant Chief for Science Operations and Strategic Planning for Goddard's Planetary Environments Laboratory, and also gave birth to a daughter. "Life is busy, but I'm having fun," Getty said.

goddard
Innovators

2007 • 2009 • 2010 • 2011 • 2012 • 2013

Tom Flatley

For Tom Flatley, the hits keep coming. Recognized in 2013 for his ceaseless efforts enhancing and finding new applications for the Goddard-developed SpaceCube flight processor, Flatley continues to find flight opportunities for the more powerful technology.

Ten to 100 times faster than current radiation-hardened flight processors, SpaceCube achieves its data-crunching prowess because Flatley and his team have married commercial, radiation-tolerant Xilinx Virtex field programmable gate array (FPGA) technology to Goddard-developed algorithms that detect and correct radiation-induced upsets. Over the years, SpaceCube has evolved into a family of products — SpaceCube 1.0, 1.5, 2.0, and the Mini. All are offering space missions an alternative for science-data processing. With the launch of the SpaceCube Mini on the Defense Department's Space Test Program-H5 mission in 2016, all four products will have been demonstrated in space, he said.

Flatley is now collaborating with the National Science Foundation's Center for High-Performance Reconfigurable Computing (CHREC) to evaluate the new Xilinx Zynq FPGA on the CHREC space processor (CSP). The CSP is currently scheduled to fly on two Goddard CubeSat missions, and as part of the STP-H5's SpaceCube Experiment Mini. Flatley also is considering its use on the more powerful SpaceCube 3.0, the latest in the SpaceCube family of products. "This technology's relatively fast evolution from laboratory breadboard to spaceflight is a testament to its value to the science communities we serve," Flatley said. ❖

Ka-Band Technology, *continued from page 10*

data throughput by a factor of more than 100 as compared with S-band."

Making the switchover to Ka-band is further complicated, Huang said, because technologists have few, if any, options to buy Ka-band hardware and components from commercial vendors. "The design is challenging and Goddard has past experience in developing reliable space hardware, and more specifically, reliable Ka-band hardware."

To overcome those challenges, Huang received R&D program support to advance what she believes is the bandwidth of the future for NASA communications in low-Earth orbit — at least until more advanced techniques, such as laser or X-ray communications, become broadly available. "Those investments have certainly paid off," she said.

"Our technology achieves high data rates and includes several innovations," Huang continued, adding that Jaso deserves most of the credit for pioneering Goddard's Ka-band technology. The Solar Dynamics Observatory, launched in 2010, used a first-generation Ka-band transmitter to deliver 300 Mbps. The Lunar Reconnaissance Orbiter, launched in 2009, contained a second-generation unit that delivered three switchable rates from 57 to 228 Mbps.

In comparison, the Goddard team has tested and verified the current third-generation technology capable of delivering 2400 Mbps (2.4 Gbps), with a higher transmitted power option of 10 watts. Instead of a fixed frequency, the third-generation operates over the entire Ka-band downlink range with a tunable data rate while in operation. Under her current IRAD award, she has started investigating the possibility of integrating data encoding as a core function of the Ka-band transmitter. "This is something that has been of interest for some future missions," she said.

"Missions will be interested in our technology not only because it provides a low-risk option, but because it can be adopted without spending on nonrecurring engineering. We're compact, low mass, and offer low-power requirements," she continued. "It really has great potential." ❖

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The world's best preserved impact site is located in Northern Arizona and is the result of a collision between an asteroid traveling 26,000 miles per hour and planet Earth approximately 50,000 years ago. Meteor Crater is nearly one mile across, 2.4 miles in circumference and more than 550 feet deep.

Who You Gonna Call, *continued from page 3*

could be knocked off course should they make a beeline for planet Earth. "An effective campaign to deal with a possible future threat really depends on our understanding of the potential threat's key physical properties, composition, and density," Seery said. That's why Goddard team members — small-body and mission experts Brent Barbee, Luke Oman, Keith Noll, and Bill Farrell — have decided to thoroughly research three different classes of potentially hazardous near-Earth objects.

This artist's rendering shows a nightmare scenario for all living things on Earth. A NASA-DOE team is studying ways to possibly deflect these ancient space rocks before they strike the planet.

The team's characterization research then will be fed into DOE's supercomputers to create three-dimensional models showing the effects of a hypervelocity impactor deployed to deflect an asteroid. The modeling data would demonstrate how best to respond to an incoming asteroid and the likely uncertainties. It also could help the community design a mission and choose the best type of mitigation strategy to employ.

"This is a unique partnership," Seery said. "By combining our respective skills, we are developing the first end-to-end integrated look at how we would respond to a potential threat under different scenarios. We think this approach will serve as a useful playbook for the community well beyond the end of our three-year study."

As Brent Barbee suggests, "we will balance the currently unfamiliar risks of potentially hazardous objects against the costs and benefits of possible responses, providing decisionmakers with the information they need to effectively defend our planet against hazardous asteroids and comets." ❖

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